Play, Dreams and Imitation in Robota

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Abstract

Imitation, play and dreams are as many means for the child to develop his understanding of the world and of its social rules. What if we were to have a robot we could play with? What if we could through play and daily interactions, as we do with our children, be a model for it and teach it (what?) to be human-like?

I advocate the use of natural human-like interaction, such as imitation, speech and gestures, for developing likable, *socially interactive robots*. As an example, I present a prototype of toy robot, the Robota doll, which can engage in complex interaction with humans, involving speech, vision and touch. Robota learns the meaning of her users' speech through natural, imitation-based interactions.

Introduction

The title of this paper is a wink to the Swiss psychologist, Jean Piaget, and to his book *Play, Dreams and Imitation in Childhood* (Piaget 1962). For Piaget, imitation, play and dreams are as many means for the child to develop his understanding of the world and of its social rules. This paper wishes to discuss the aspects of these behaviors which make them relevant to research on socially intelligent agents (SIA).

Imitation

Imitation is a powerful means of social learning, which offers a wide variety of interaction. One can imitate gestures, postures, facial expressions, behaviors, where each of the above relates to a different social context. An interesting aspect of imitation in humans (perhaps as opposed to other animals) is that it is a bidirectional process (Miklósi 1999). Humans are capable to recognize that they are imitated. Imitation becomes also a means of teaching, where the demonstrator guides the imitator's reproduction.

Roboticists have used imitation as a means for teaching the robot motor skills, e.g. for recording its path (Demiris & Hayes 1996; Gaussier *et al.* 1998), for climbing hills (Dautenhahn 1995) or for controlling the movements of a humanoid ((Billard 2000b), (Cooke *et al.* 1997), (Demiris 1999; Demiris *et al.* 1997), (Schaal 1997), (Kuniyoshi & Inoue 1994)). Robotics implementation of social skills is driven by two different aims. On the one hand, it seeks to enhance the robot's ability to interact with humans by providing it with natural, socially driven behaviors (Dautenhahn 1999a). On the other hand, the robot (or the mechanical simulated agent) is a platform for testing a model of a particular animal behavior. For instance, (Billard 2000b; Demiris 1999; Demiris *et al.* 1997) investigated models of the neural and cognitive mechanisms behind primates' ability to imitate, using either a mechanical simulation of a humanoid (Billard 2000b) or a real robot (Demiris 1999; Demiris *et al.* 1997). Mechanical simulations, which include a complete simulation of the dynamics of the avatar's body and of the world, are similar to robotics experiments in that they use a realistic, embodied agent and accounts for the dynamics of the agent with its environment (situatedness). In agreement with (Brooks 1991; Dautenhahn 1997), I believe that embodiment and situatedness are essential to gain complete understanding of the mechanisms underlying sensory-motor coordination and to evaluate the validity of a model which represents a behavioral (as opposed to purely cognitive) competence, as it is the case when modeling, e.g., animals' ability for imitation.

Another interesting aspect of imitation lies in that it allows imitator and demonstrator to share a similar set of internal perceptions. I exploited this idea in experiments in which the robot's ability to imitate another agent, robot or human, was used to teach it a synthetic proto-language (Billard 2000a; Billard & Dautenhahn 1999; Billard & Hayes 1999). There, movement imitation is an implicit means of teaching. It is a means to direct the robot's attention to specific perceptions of movement, inclination, orientation, for which it is taught words and sentences to describe those perceptions. The Robota doll, which I describe below, exploits this imitation-based learning scenario.

Play

Entertainment robotics is one of the many fields which will benefit from the development of socially intelligent agents. Entertainment robotics aims at creating playful, autonomous creatures. But, then, what are the features which makes a robot entertaining, a possible toy?

I would argue that an interesting toy is often a toy which offers a challenge, where, by playing with the toy, one dis-

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covers many means of using it. This can be true of the simplest toy, such as a wooden stick (which can be used as a litt, a drill, a bridge or a limb as part of a stick figure). A boring toy is a toy whose use is limited and immediately understood. Thus, an interesting robotic toy should show several means of interaction with the child. These should include responding to touch and handling, gestures, vocal expression and, if possible, speech, as well as learning and adaptability.

For psychologists (starting with Piaget), children's games are as much an educational tool as an entertainment device. Thus, entertainment robotics also seeks to develop educational tools. The project Aurora, directed by Kerstin Dautenhahn, follows such a direction, by developing social behaviors for a mobile vehicle robot for interacting with autistic children (Dautenhahn 1999b). Similar line of research is also pursued by (Cassell & Vilhjlmsson 1999) and in the commercial domain by, e.g., Knowledge Adventure company.

Interesting is the parallel advanced by A. Miklosi (Miklósi 1999) between imitation and play. He notes that imitation often occurs during play and argues that "the context of play offers a special, state of mind (relaxed and free from any immediate need) for imitative behavior to emerge". Thus, what if we were to have a robot we could play with? What if we could through play and daily interactions, as we do with our children, be a model for it and teach it to be human-like?

Making one's toy more personal is the wish of most children. Tools of artificial intelligence which provide adaptive and learning abilities or allow to simulate development are very suitable for this purpose. Proof is the large success encountered by the video game *Creatures*, the Japanese electronic devices *Tamagochi* and toy robots, such as the LEGO *Mindstorms*, the *Furbys* and the Sony pet robot.

I advocate the use of natural human-like interaction, such as imitation, speech and gestures, for developing likable, petlike toys. As an example, I present Robota, a doll robot which can engage in complex interaction with humans, involving learning of speech and child games using music, vision and imitation.

Robota

In (Billard 1999; Billard, Dautenhahn, & Hayes. 1998), I presented a first prototype of Robota. There, I reported on experiments in which the robot could be taught a protolanguage to describe its interaction with the teacher, such as that of motion and of perception of touch on different parts of its body. In this paper, I present a second prototype of Robota, which underwent sophisticated hardware and software improvements, largely increasing its repertoire of interactions. Figure 1 shows a picture of the two robots, the first prototype on the left and the second on the right.

The robot's hardware

Body Structure The body of the robot is that of a commercial doll. The mechanics for driving the motors is entirely contained in the body. The microcontroller (Kameleon 376SBC board [1]) and electronic interfaces are on-board of the robot, attached as a backpack (see figure 3). These electronic circuits control the robot's built-in behaviors and the learning of melodies and dance movements. The robot has a rechargeable battery of 30 minutes duration, which is contained in the backpack. The robot can also be powered externally through a power supply. It requires about 2 to 4A at 6V.

Figure 1: The two Robota dolls. The first prototype is on the left and the second prototype on the right.

Figure 2: The teacher guides the robot's motions using a pair of glasses holding a pair of IR emitter. The glasses radiation which can be picked up by the robot's "earrings" IR receptors.

Actuators and Sensors

The new prototype of Robota has the same abilities for imitation as that of the first prototype. That is, it can mirror the arm and head movements of a demonstrator, following a bidirectional infra-red set-up, see figure 2. In addition to moving the arms and the head, the second Robota can walk forwards and backwards by making small saccadic stepping.

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[1] The Kameleon board is produced by K-Team SA, www.k-team.com.

It has a electronic magnet inside the right hand which allows it to hold a baby bottle. Aside the magnet is a switch which allows the robot to detect when an object is inserted in its hand. It has numerous sensors (switches on the hands, head, mouth, leg, inclination sensor, IR-proximity sensors, pyroelectric sensor for detecting human movements).

External devices

Similarly to the first prototype, the second robot can be connected to external devices: a pair of glasses and a pair of hand sensors for the imitation set-up (see figure 2) and a keyboard. The keyboard contains a set of eight keys, a loudspeaker, a 6-positions joystick. The whole is controlled by a chip (PIC). The keyboard is preprogrammed to play one note of the musical scale for each of the eight keys. That is, the 8-keys of the keyboard is an electronic xylophone. The robot has also a microphone inside the body which allows it to repeat the sounds (with its own voice). The joystick allows one to direct the robot's arm and head movements (lifting up and down the arm and shaking the head on the sides). This provides an additional means, on top of the glasses/hand sensors set-up (allowing mirroring of hand and head movements), to direct the robot's arm and head movements.

PC connection

The robot can connect through a serial link to a PC[2]. A PC-robot interfacing program allows one to interact with the robot through speech and vision. A Quickcam camera is attached to the PC and allows the robot to detect human presence, using a simple color and motion processing algorithm. Recognition of speech is provided by a commercial speech processing software (for French and English), running on the PC. Speech is translated into ordered strings of words (written language). These are used by the PC interface program to learn a language, that is, to extract words of the sentences and attach them a meaning in terms of the robot's perceptions (sensor and actuator states of the robot are passed to the PC through the serial link), see (Billard 2000a; Billard & Hayes 1999) for an explanation of the principle. The learning algorithm is provided by an artificial neural network, called DRAMA (Billard & Hayes 1999), which has general properties for learning time series. Once the language is learned, the robot can talk with the user through the PC loudspeaker. The DRAMA learning algorithm runs also on the robot and allows the robot to learn melodies (as played by the user on the keyboard) and to learn dance patterns for each melody (by associating sequences of movements with sequences of notes).

In addition, the PC program can start-up music files (MP3 or CDs). This is used to provide the robot with play behavior. The robot spontaneously puts on a music and starts dancing (i.e. moving backwards-forwards and making head and arm movements), making a different dance for each music. It can also play baby-like sounds, such as laughing and crying, which it does depending on its mood.

Figure 3: The second prototype of Robota is a standalone robot. It can be connected to a PC for speech and vision-based interaction. The reproduction of the photos are a courtesy of Eurelios.

A Toy and Educational Tool

Robota features several means of interaction with a human. It can be taught a language, using real speech input. It can learn dance movements (sequence of stepping, arm and head movements) and learn to do these for a specific music, which can either be prerecorded in a CD-Rom or taught using the musical keyboard. The robot has several baby-like, built-in behaviors, implemented as a set of internal variables which vary over time. For a given set of values, the robot will start to cry, laugh, sing or dance. Current developments work towards implementing a set of Robota avatars, based on my

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[2] The code for the PC is written in C and C++ and runs both under linux and windows 95/98. It was tested on a HP4100 laptop, Pentium II, 266MHz, 96M and was shown to run on real time.

dynamic simulation of a humanoid (Billard 2000b), which could interact with the real one via the PC connection.

The multimedia type of interactions, which offers Robota, makes it a non (not immediately at least) boring toy. In (Billard, Dautenhahn, & Hayes. 1998), we reported on tests with children of 5 and 6 years old, which showed the potential of the system as a game for children. The children enjoyed playing with the robot because they could interact with it in different ways. The robot would respond to the children touching specific parts of its body, by making small movements or little noises. It would mimic the child's head and arm movements. It would speak words which are part of the child's every-day vocabulary (e.g. *food, hello, no*). Imitation is a game that young children like to play with each other and their parents, thus it was easy for them to understand that they could interact with the robot in this way.

The robot could also be used as an educational tool. The level of complexity of the game with Robota can be varied. One can restrict oneself to only interact with the built-in behaviors of the robot (a baby-like robot). The learning game can be restricted to learning only music patterns (using the musical keyboard), dance patterns or speech. The robot could, thus, be used to train and possibly test (in the case of retarded children and, e.g., for evaluating the deepness of autism) the child's motor and linguistic competences. Because of the different levels of complexity of the robot's controller, one could expect to interest children from 5 to 10 years old.

Dreams

To conclude this paper, I wish to share my dream as roboticist to develop a truly believable, human like robot and give you rendezvous in November with the little Robota.

Acknowledgments

The second Robota doll was built at the Laboratory of MicroInformatics at the Swiss Institute of Technology in Lausanne (EPFL), thanks to the generosity of Professor Jean-Daniel Nicoud, who also developed the electronic interface which drive the motors and sensors. The main electronic board, Kameleon, is a commercial product developed by K-Team SA. I am responsible for the design of the two prototypes of Robota and for the development of their control systems, as well as for the development of the PC interfacing system.

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